



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

BIOLOGICAL BULLETIN

THE BREEDING BEHAVIOR OF THE SUCKERS AND MINNOWS.

I. THE SUCKERS.¹

JACOB REIGHARD.

CONTENTS.

I. Introduction to the Series.....	1
II. Breeding Behavior of the Suckers.....	3
A. The White Sucker.....	3
1. The Breeding Grounds and Breeding Season.....	3
2. General Activities of Breeding Fish.....	4
3. Coloration and Color Changes.....	6
4. Sexual Differences.....	6
Color.....	6
Pearl Organs.....	7
Fin Length.....	8
5. Breeding Activities.....	9
B. The Common Red-horse.....	15
1. Breeding Grounds and Breeding Season.....	15
2. Sexual Differences.....	16
3. Coloration.....	18
4. Breeding Activities.....	19
C. The Hogsucker.....	20
1. General Activities.....	20
2. Sexual Differences.....	21
3. Breeding Activities.....	22
III. Summary of Observations.....	
A. The White Sucker.....	24
B. The Red-horse.....	26
C. The Hogsucker.....	28
IV. Conclusions.....	29
V. Literature.....	31

I. INTRODUCTION TO THE SERIES.

This paper is the first of a series on the breeding habits of nine species of suckers and minnows. These fishes form a well-defined group by some systematists united into a single family,

¹ Contributions from the Zoölogical Laboratory of the University of Michigan.

by others separated into the Catostomidæ and Cyprinidæ. To accumulate the field notes and sketches on which the papers are based has been the work of many seasons. If there were no bad weather, no university duties, and no human interference with breeding environment or breeding fish, such work might be carried on with as little interruption as that of the laboratory; but it would not progress as rapidly, for observations need to be many times repeated. The behavior is often so complicated or so rapid that it is only by analyzing it into its elements and observing each of these repeatedly that a degree of certainty is possible. Such attitudes as these shown in Fig. 3 of this paper may be correctly represented only after many observations on the position of each fin and on every other detail. The observations upon which my descriptions are based have been very many for each element of the behavior, often in the neighborhood of a hundred, sometimes probably several hundred, or even thousand. Although the work has been spread over a period of years no one should suppose that the record is complete. I have studied *only the breeding behavior* and that in but few fishes; I have not the life history or the full natural history of any one. Of the breeding behavior I shall try to give for each species a composite picture taken from many fish through many seasons. This I give in such detail as I have, because that seems necessary to clearness. It further affords a better basis for the discussion of theories to be considered in the final papers of the series. The behavior that I describe may be easily seen in suitable places and at the proper season. Yet few are likely to take the trouble. This has seemed to me an added reason for fullness of treatment.

The suckers and minnows that I have studied, with the exception of the blunt-nosed minnow, *Pimephales notatus* (Rafinesque) breed in running water. During the breeding season the males of all the species studied have pearl organs, hard, tough, white, usually conical elevations of the skin which consist of cornified epidermal cells. They occur in many situations. Some of them are so small as to be visible only under a lens; others may be seen with the naked eye at a distance of ten or twelve feet. They commonly make the surface of the breeding males distinctly rough to the touch and are in that case referred to as "effective" pearl organs.

The drawings that show fish in action have been made from field notes and sketches with the help of specimens and in some cases with the aid of models or photographs. I am indebted to Mr. Charles R. Knight for valuable suggestions in connection with the drawings but he is in no way responsible for their obvious shortcomings. To my former student, Professor Norman H. Stewart, of Bucknell University, I am indebted for data from his unpublished manuscript on the distribution of the pearl organs. To the United States Commissioner of Fisheries, Doctor Hugh M. Smith, I am indebted for permission to publish.

2. BREEDING BEHAVIOR OF THE SUCKERS.

A. *The White Sucker* (*Catostomus commersonii* LeSueur).

1. *The Breeding Grounds and Breeding Season.*—A little way from the State Bass Hatchery, near Grand Rapids, Michigan, Mill Creek is spanned by a bridge of the Pere Marquette Railway. Just below the bridge, where the stream is three or four rods wide, a line of four-inch waterpipe is laid across its bed. An eighth of a mile above the bridge the stream is dammed to furnish water for the hatchery. Between the dam and the pipe-line it is made up of a series of alternating rapids and pools. For a little distance above the bridge and beneath it the water runs six to twelve inches deep, swift and smooth. Below the pipe-line it breaks into ripples. Under the smoother water the bottom is sandy gravel, but under the broken water this gives place to larger stones. Over the gravel in the smoother water a thin brown mantle of silt and algal growth usually stretches without interruption from shore to shore and obscures the bottom.

Rapids of this sort are typical of a drift-covered country and afford the characteristic breeding ground of the white sucker.¹ In the spring patches of the gravel bottom in the upper water of the rapids often look as though they had been scoured by a broom. The silt mantle is absent from these patches and the bright colors of the clean gravel and sand throw them into

¹ The usual name in Southern Michigan; known also as common sucker, fine-scaled sucker, brook sucker.

I am indebted to Professor W. M. Smallwood for permission to use his unpublished notes on this species. He records seeing it in the spawning attitude on stony bottom in Lake Clear in the Adirondacks in late June (*cf.* Reighard, 1915).

sharp contrast with the surrounding silt-covered bottom. The patches show where the suckers have been breeding.

The water of a rapid is rarely so smooth that one can see readily into it. Not often is such a rapid near a bridge or other perch; but under this Mill Creek bridge the surface of the stream is but little broken and on a sunny, cloudless day, when the water is clear and there is no wind to ruffle its surface, it is possible to see in detail what happens on the rapid. With field glasses the fish may be studied almost as readily as though they were in air. From this vantage point I watched the white suckers at intervals.¹

My work was done by day. It is well known that in the spring suckers ascend small streams in great numbers at night and it is possible that their breeding activities are continued at night. They are often interrupted by colder weather or roily water.

2. *General Activities of Breeding Fish.*—About 2 o'clock on April 23, 1903, I cautiously took my place on the Mill Creek railroad bridge. Numerous white suckers were on the rapids. Although I walked with extreme slowness and made no sudden movements of any part of my body the fish were at once aware of my coming and scurried to the shelter of the banks and nearer pools. I sat quiet and in the course of fifteen minutes they began to reappear in the shallow, swift water. Thereafter, for an hour, any quick movement on my part resulted in the fish starting swiftly up stream, but if the movement was not repeated they dropped slowly down-stream to where they had been. To get the field glasses to the eyes or the hand to the notebook without startling the fish needed a movement so slow that it must have been scarcely perceptible at the distance of twenty-five or thirty feet at which the fish were. It was probably about two inches per second. As time went on the fish became gradually used to my presence and after an hour were no longer disturbed by slow movements. By three o'clock twenty suckers from eight to twelve inches long were on the rapid and were moving slowly up stream in small groups. The fish stopped

¹ From April 23 to May 6, 1903. In Honey Creek near Ann Arbor, I saw them breeding April 27 to May 2, and in Mallet Creek, Ann Arbor, on May 10, 1909. The two creeks last named are only about a third the width of Mill Creek (Grand Rapids) at the point at which the suckers were seen.

here and there in the rapid on the patches of cleaned gravel and were seen to take gravel into the mouth and spit it out. They were presumably in quest of eggs that had been laid in the disturbed gravel areas and their occurrence in small groups is perhaps in part the result of the distribution of such areas. In their search they were accompanied by numerous small minnows doubtless on the same quest. Other suckers were seen crossing the pipe-line. At four o'clock no suckers were to be seen from the bridge, but a dozen were found just below the dam an eighth of a mile further up stream. The fish had apparently covered this distance in an hour. At nine o'clock the same evening the search light showed suckers still crossing the pipe line bound up stream.

In my experience the white sucker is one of the most difficult of our native fishes to approach in the open. Ordinarily it becomes accustomed to the observer with extreme slowness and at no time permits him any great freedom of movement. Confined with other fish in an aquarium it is among the last to become accustomed to the observer or to take food.¹

¹ I have noted but two exceptions to this general fact. (1) On May 6, in the morning, I placed in an outdoor aquarium at the Mill Creek Hatchery four males and two females that had been captured in a seine on the previous evening. At three o'clock on the same day the fish were moving about and feeding and by four o'clock they were spawning. They did not react to an observer within two or three feet of them. (2) At Douglas Lake in Cheboygan County, Michigan, suckers are found in rather deep water. At night they come into shallower water to feed and are occasionally seen there at dawn. At such times they flee to the deeper water at the first glimpse of a moving object. In late June the log perch (*Percina caprodes*) are laying their eggs in the sand in very shallow water. At that time suckers enter shallow water in the day time and feed on the eggs of the log perch. Each sucker is accompanied by a group of log perch which appear to be feeding on eggs uncovered by him and perhaps on other crumbs from his table. At this time the suckers may be approached with little trouble and I have come close enough to photograph them as they lay at my feet. I have thought this absence of the suckers' usual wariness due to the presence of the log perch. These are breeding and are then unafraid. In deeper water the sucker has probably found freedom from disturbance where they were present. Safety and log perch have been closely linked in his experience. So now, so long as the log perch are on the shallows, he is not easily startled and feeds there undisturbed by sights that would otherwise send him hurrying to shelter.

To these observations may be added one of Smallwood (unpublished notes). At the end of June he found *Calostomus commersonii* and two other species of sucker on stony bottom in the shallow water of Lake Clear in the Adirondacks.

3. *Coloration and Color Changes*.—The mature white sucker, when seen in its native waters or in captivity, is ordinarily uniformly olivaceous on the back and sides and white below. There is no color pattern nor are there color differences between the sexes. The suckers seen from the bridge (Fig. 4) were so different in coloration from all that I had seen before, that I was at first doubtful as to their identity. Each had a broad yellow-white stripe which crossed the occiput and extended thence down the sides. When some of these fish were seined they were found to have the usual uniformly olivaceous color. They were placed in an aquarium, males and females together, and four hours later the males had begun to move about and to feed. Shortly afterward the light stripe appeared across the occiput and down the sides. Beneath the light stripe was a broad dark stripe (Fig. 4) and in one of the males this had a rosy tinge. During the actual pairing described below, the rosy tinge gave place to a brilliant crimson. Later I often saw the light stripe appear in a few seconds on uniformly colored males that were on the rapids. This happens regularly in the breeding season when the sexes are together.

4. *Sexual Differences*.—It is at first difficult to discriminate between males and females. As seen from the bridge the paired fins are transparent white in both and in both the yellowish white stripe crosses the occiput and extends down the sides. But the males are on the average smaller than the females and slenderer. It is soon apparent that the occipito-lateral stripe is whiter in them and that their backs may be flecked with white especially between the dorsal fin and the occiput (Fig. 4, male at right of female). In the region of the occiput the white flecks may form a distinct patch which, seen from a distance, looks like fungus. The white flecks are perhaps not always present in males, but I have never seen them in females. In pairing males, seen in the aquarium, the dorsal half of the eye is lighter colored than in females, but I do not know that this is not the case at other times. The differences so far noted afford *C. commersonii* and one of the other species, probably *C. catostomus*, were seen in the spawning attitude. The fish were not disturbed when a boat, in which were two children and a barking dog, was poled about above them so that they were not more than five feet from it.

excellent field characters by which the sexes of the breeding fish may be distinguished in their native waters. Less striking differential characters are the greater length of the caudal and lower fins of the male, the difference in length of his caudal lobes and his possession of pearl organs.

Effective pearl organs (*vide* introduction) occur on the male in the following situations (Fig. 1): (1) Large, sharp-pointed

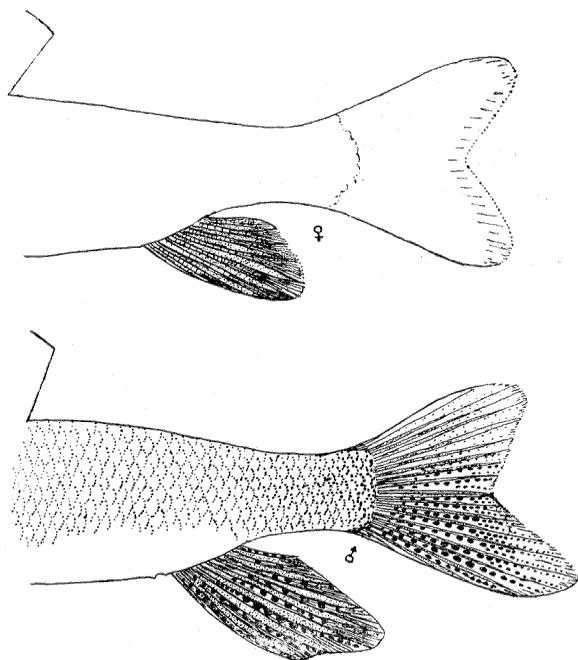


FIG. 1. Lateral view of a part of a male and female of *Catostomus commersonii* drawn to the same scale. The black dots represent pearl organs. The anal fin and lower lobe of the caudal are longer in the male and bear large pearl organs. All the scales of his sides bear small pearls, somewhat larger behind the caudal. The female has no pearl organs.

organs are found on the anal fin and on the lower part of the caudal. They may be visible to the unaided eye at a distance of three or four yards. (2) The caudal margins of the scales on the sides bear small hemispherical organs, which are effective behind the dorsal. (3) The upper surfaces of the pectorals and both surfaces of the pelvic fins bear small organs. (4) The rays of the dorsal fin bear small organs. Pearl organs do not occur in the female (Fig. 1).

The difference between the sexes in fin length are shown in Table I.

TABLE I.

SHOWING IN MILLIMETERS THE AVERAGE LENGTH OF FINS IN MALES AND FEMALES OF *Calostomus commersonii* OF EQUAL LENGTH, THE DIFFERENCE IN AVERAGE LENGTH OF FINS AND THE PERCENTAGE DIFFERENCE.

	Length, Tip of Snout to Base of Caudal.	Caudal Lower Lobe, Length.	Anal, Length.	Dorsal, Length.	Pelvic, Length.	Pec- toral, Length.
Males, M.....	312	62	65.5	47.8	42	57.5
Females, F.....	312	54.6	49.8	45.7	37.7	51
Difference, D = M - F.	000	+ 7.4	+15.7	+ 2.1	+ 4.3	+ 6.5
Percentage of Difference, % D = (M - F):F.	000	+13.4 (+31.1)	+31.5	+ 5.0	+11.4	+17.8

By fin length is meant the greatest distance from base of fin to its margin, approximately the length of the longest fin ray. The table is based on nine fish of which six were males. The males ranged in length from 260 to 405 mm. with an average of 312 mm. All had well developed pearls. The females averaged 263 mm. in length (210, 215, 365). In order to compare fish of equal length the female average length has been made equal to that of the male and the average fin lengths of the females as obtained from measurements have been corrected in proportion. The figures in the lower horizontal line therefore show in percentages the sex difference in length of fins in fish of the same length. Since the caudals of two of the females were broken there is added for the caudal a corrected percentage (31.1) obtained by comparison of a single male of 340 mm. length with a female of 365 mm.

From the table it appears that in fish of equal length the anal and caudal (lower lobe) of the male are about 31 per cent. longer than those of the female; the pectoral about 18 per cent. longer; the pelvic about 11 per cent. and the dorsal only 5 per cent. In the female the caudal lobes are of about equal length whereas in the male the lower lobe in two perfect specimens averaged about 10 per cent. longer than the upper. The fins appear to differ in robustness in about the same proportion as in length. This is shown by the width at mid-length of the longest anal ray in a male and female of equal length; in the male 4.5 mm. in the

female 2.6 mm. In smaller individuals there is no great difference between the length of fins in individuals of opposite sexes, but these differences appear with increasing size. A male of 135 mm. when compared to a female of 137 mm., had slightly shorter dorsal, caudal and pectorals, but somewhat longer anals and pelvics.

It is to be noted that in adult specimens those fins of the male (lower caudal lobe, anal) that bear the largest pearl organs also exceed the corresponding fins of the female by the largest percentage. (Cf. Table I. and Fig. 1.) Indeed the fins of the male may be divided into three groups on the basis of the percentage by which they exceed the corresponding fins of the female; the anal and caudal with 31 per cent. excess; the pectoral and pelvic with 10 to 20 per cent. and the dorsal with 5 per cent. The size of the pearls borne on the fins of these three groups is roughly proportional to these percentages.

When the fish are seen close at hand, or under favorable conditions with field glasses, the pearl organs of the male and the greater size of his anal fin suffice to distinguish him from the female (Fig. 1). But were the sexes identical in form, size and color, the behavior differences described in another place would differentiate them.

5. *Breeding Activities.*—During the breeding season males are at all times much more numerous on the rapids than females and during the greater part of the time none but males are present. It does not follow that males are actually more numerous than females. On the contrary data that I have collected at other localities and at times when the fish were not breeding indicate that the males and females are equally numerous. (Reighard, 1915.) In the breeding season the females do not mingle with the males on the rapids until ready to lay their eggs. But from time to time a female comes from her retreat in the deeper water above or below the rapid or from beneath the bank and takes her place on the rapid. If no males happen to be near she may lie quiet in one place for a considerable time. But if males are near they at once approach her, sometimes one or two, sometimes as many as ten. Pairing is best seen when but two males are involved and will be first described under these

conditions. As the males approach the resting female she hurries forward as though to escape, but presently stops with her belly on the bottom. As the males again approach she hurries forward a second time, but soon stops as before. Thus she appears to be driven here and there over the spawning ground, too "coy" to allow the males near her. After a varying number of apparent efforts to escape her "coyness" vanishes and she rests quietly on the bottom and permits the males to come near. In what follows I describe the spawning behavior as I saw it very many times from the bridge or from the banks of Mill Creek. Details were observed several times in the aquarium (Fig. 4).

When a male comes within a few inches of the waiting female he is often seen to stop, spread his pectorals, erect his dorsal and protrude his jaws (Fig. 4, second fish from bottom). Then, for perhaps a second, his head trembles with a slight, rapid vibration from side to side. The movement is not unlike the tremor of a palsied hand. It is like the tremor that one may produce in his own head by strong continuous contraction of the muscles of the neck. This tremor may be seen not only when a male approaches a female, but often when he approaches another male on the spawning ground. I have never seen it in a female.

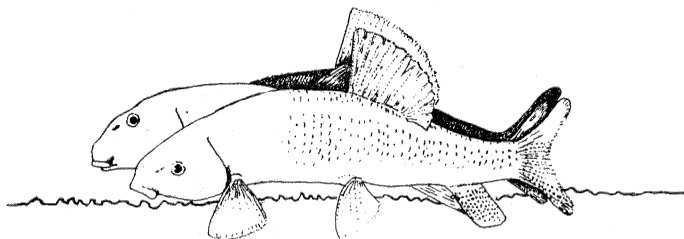


FIG. 2. A female of *Catostomus commersonii* engaged in pairing, with a male on each side of her. The body and tail of one male are shaded. The pearl organs are shown on the anal and caudal of the nearer male, but not elsewhere. The figure represents the pairing act near its end with the head of the female well above the bottom, which is represented by the irregular horizontal line. Drawn with the help of a photograph (see Fig. 4).

It is probably nothing more than a beginning of the tremor of the whole body which accompanies spawning. It necessarily produces a vibration in the water which may be of such a rate as to stimulate other fish through the skin, ear or lateral line

organs (Parker, 1917). In many fishes the spreading of the dorsal at the breeding season results in the display of a conspicuous marking or color pattern (Reeves, 1907 and citations). This is true of some of the minnows to be described in later numbers of this series. *It is noteworthy that in the suckers, although the dorsals are unmarked, the display movement (Fig. 2) does not differ from that of those fishes that have a conspicuous dorsal.*

As the male approaches the female another change becomes evident. The dark stripe on his side (Fig. 4), which may have become rosy a little while before, now suddenly turns to a vivid scarlet and remains so during the pairing. At the same time the eye becomes red and continues so while the female is present.

The males with fully extended pectorals and erected dorsals now press close against the female one on either side (Figs. 2; 3).

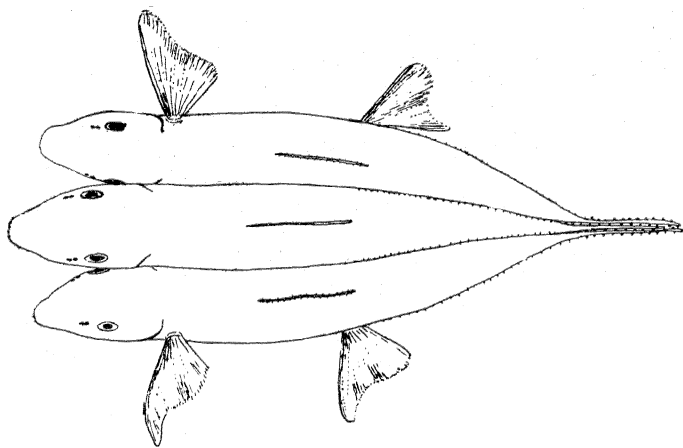


FIG. 3. Diagram showing the pairing of *Catostomus commersonii* as seen from the dorsal side. Compare Fig. 2.

The smallest males that I have seen pairing were about six inches long. The two are usually of the same size and commonly are a good deal smaller than the female. But they are not always of the same size and one or both may be as large as the female.

When the males are in position (Figs. 2, 3) their adjacent pectorals are spread beneath the female. Their caudal fins press on either side against that of the female, but may extend for some distance behind and below it, so that their distal parts press against each other. Their anals are spread and extended

downward so that they press against the sides of the tail and sometimes against the anal of the female. The backs of the males are arched and their dorsal fin-rays, spread like the ribs of an extended fan, stretch the membrane between them (Figs. 2, 3).

The lateral surfaces of the anal and caudal and the sides behind the dorsal, all of which are roughened by pearl organs (Fig. 1) are thus pressed vise-like against the female so that she is firmly held (Figs. 2, 3). But the roughened caudals and anals of the two males also press against each other where no part of the female separates them. Thus the pearl organs aid males to keep their positions with reference to the female as well as to each other.

When the fish have come into position there is a rapid vibration of the whole bodies of all three together. This is wide and vigorous behind the dorsal fin, while in the region of the head it is a little more than a tremor. At this time the fish are often in water so shallow that their backs are exposed. The powerful movement of the tails of the three fish stirs up the gravel and a cloud of sand is released and washed downstream. At this time, in the aquarium, one may see milt spurt from the genital openings of both males and cloud the water. No doubt the eggs are extruded at the same instant and buried in the gravel, but the water is made so turbid by sand and milt that I have not seen the eggs laid. I have estimated the length of the spawning act at a second and a half but have not actually timed it. It is often repeated especially by the larger males. Large males are often taken in which the front edge of the anal fin is raw and worn by rubbing against the gravel. I have seen nothing of the sort in females, but their anal fins are smaller than those of males and are protected by them during the spawning act, while the number of pairings of the average female can be but half that of the average male.

When a pairing act is completed the female moves on, usually upstream, and presently pairs with other males on another part of the breeding ground. Her eggs are thus scattered in small lots over a considerable area, very likely over more than one rapid and are commonly fertilized by many pairs of males. The two

males separate, the red stripe on their sides and the red in their eyes fades, but the white occipito-lateral stripe remains for some time. Each male now moves about and feeds as before. And so they continue until another female appears when one or both may succeed in pairing with her and this may happen on any part of the spawning ground. Thus the eggs fertilized by one male may lie anywhere in the gravel of a rapid or in that of several rapids. The breeding activities are in no way centered about individual males, for the coöperation of two males in pairing makes it impossible to know what eggs are fertilized by an individual male.

I have never collected from the bottom the eggs laid at a single pairing. But the smaller fish lurking in the neighborhood tell one plainly enough where they are. The black-nosed dace (*Rhinichthys atronasus*) and the rainbow darter (*Etheostoma caeruleum*) gather at once in great numbers over the spot where the pairing suckers were. They come in a straight line from down stream attracted, no doubt, by the trail of milt, eggs or bottom materials swept down by the current. They gather in an area six or eight inches across and each burrows in the bottom with its snout as though seeking eggs. The whole little area is soon concealed by their wriggling tails, close-set like threads in the pile of velvet. Some of the eggs may have been swept down stream, but many of them must be buried where the small fish are rooting.

When more than two males follow a female (Fig. 4) it may be difficult to see what happens. When she finally stops the two males nearest or most vigorous in the pursuit attempt to pair with her. But the others at once crowd about and try to force their way between her and her mates. They try either to squeeze in at the sides of the female from above so as to force her mates outward, or to wedge themselves beneath the pairing males from the side so as to force them up and take their places. But once the two males have the female firmly held between them it is difficult to dispossess either and I have never seen this happen. As many as ten males have been seen with a single female during the spawning act, and the act was nevertheless completed; but often, when many crowd about, she interrupts

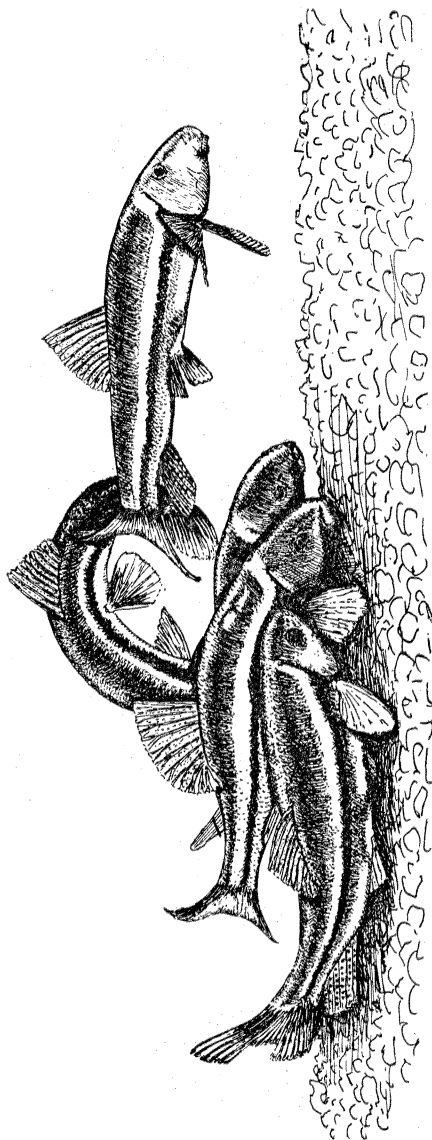


FIG. 4. Group of breeding *Catostomus commersonii*, consisting of one female and four males. The second fish from the right, with head only showing, is the female. One male has taken position on the right side of the female while another with his head hidden by the female's body is coming into position on her left. The males at the right and left are supernumerary. Pearl organs are visible on the anal of two males. Drawn from a photograph of fish in an aquarium.

the pairing and moves upstream as though seeking an opportunity to pair unmolested. This she may secure and the pairing then takes place in the manner already described. Although supernumerary males may be present and may attempt to interfere they take no part in the normal pairing. While they crowd about the female and attempt to gain a place at her side, there are no combats between them. When not at the side of the female they seem to pay no attention to one another.

When the breeding season is over the male suckers lose their pearl organs. They were beginning to shed them in southern Michigan on May 13, 1913. Both sexes become uniformly olivaceous on sides and back. They are no longer commonly seen on their breeding grounds, and in Michigan most of them seek deeper waters.¹

B. The Common Red-Horse (Moxostoma aureolum Le Sueur).

1. *Breeding Grounds and Breeding Season.*—In southern Michigan the red-horse breeds in May. My two dates are May 17, 1904, and May 4, 1905. On these dates the breeding season of the white sucker was nearing its end. While the breeding grounds of the two species are the quieter, upper parts of rapids in shallow water with gravel bottom and, while the two species often breed in the same rapids, I have not found the red-horse in streams as small as those sometimes frequented by the breeding white sucker. The sucker may spawn in brooks so small that one may step across them but I have found the

¹ In Walnut Lake Hankinson (1908) reports the species in water 15-40 ft. in depth in summer and a few were found in a restricted part of the lake in water 80 ft. in depth in April and May. I have found it in Douglas Lake, Cheboygan County, Mich., from July to September in water up to 45 ft. in depth (Reighard, 1915). Smallwood (unpublished notes) reports the return of suckers to Lake Clear after breeding in Sucker Brook. On the other hand Forbes and Richardson (1908) say: "It is with us essentially a species of creeks and smaller rivers, nearly four times as common, according to our data in the former as in the latter. . . . Our collections show that it is much more likely to be abundant on bottoms with more or less rock and sand than on a completely muddy bottom and that it has also a decided preference for clear, swift water." Without a knowledge of the dates at which Forbes and Richardson's collections were made or of the size of the fish taken it is not possible to say to what extent adult suckers collected by them occur on the rapids at other than the breeding season. Certain it is that they are abundant in the deeper water of some inland lakes of Michigan and in the Great Lakes when not breeding.

breeding red-horse in streams not less than thirty or forty feet in width.

2. *Sexual Differences*.—There are no known color characters by which the sexes of the red-horse may be distinguished with certainty at any season but there are structural differences. According to Forbes and Richardson (1908) the lower fins are "longest in the male." Table II. has been made in the same way as Table I. (See p. 8.) The averages were obtained from five males and two females, all breeding fish. It shows that all the fins of the male are longer than those of a female of the same length with the possible exception of the caudal. The caudal appears to be 5 per cent. shorter in the male. But since some of the caudals are imperfect a comparison was made of a single perfect male of 205 mm. with a perfect female of 280 mm. on the basis of equal length. This shows that the upper lobe of the caudal is 12 per cent. longer in the male and the lower lobe 33 per cent. longer. The latter value is included in parentheses in the table. The anal and pectoral are longer in the male by about 15 per cent. The dorsals and pelvics are longer by about 10 per cent. The lower lobe of the caudal of the male is not only longer than that of the female, but about 14 per cent. longer than the upper lobe. In the female the two lobes are of equal length.

TABLE II.

SHOWING IN MILLIMETERS THE AVERAGE LENGTH OF FINS IN MALES AND FEMALES OF *Moxostoma aureolum* OF EQUAL LENGTH, THE DIFFERENCE IN AVERAGE LENGTH OF FINS AND THE PERCENTAGE DIFFERENCE.

	Length, Tip of Snout to Base of Caudal, Mm.	Caudal Lower Lobe, Length.	Anal, Length.	Dorsal, Length.	Pelvic, Length.	Pectoral, Length.
Average for 5 males, M.	239	56.8	50.4	47	36.2	49.2
Average for 2 females, F.	239	60	44	43	33	31.5
Difference, D = M - F	000	- 3.2	+ 6.4	+ 4	+ 3.2	+ 7.7
Percentage of Difference, % D = (M - F) : F	000	- 5.3 (+33)	+14.5	+ 9.3	+ 9.4	+15.8

The breeding males are further distinguished by the possession of conspicuous pearl organs. (Figs. 5, 6.) On the end of the snout and sides of the head as far as the caudal margin of the preoperculum are numerous large sharp-pointed organs, more

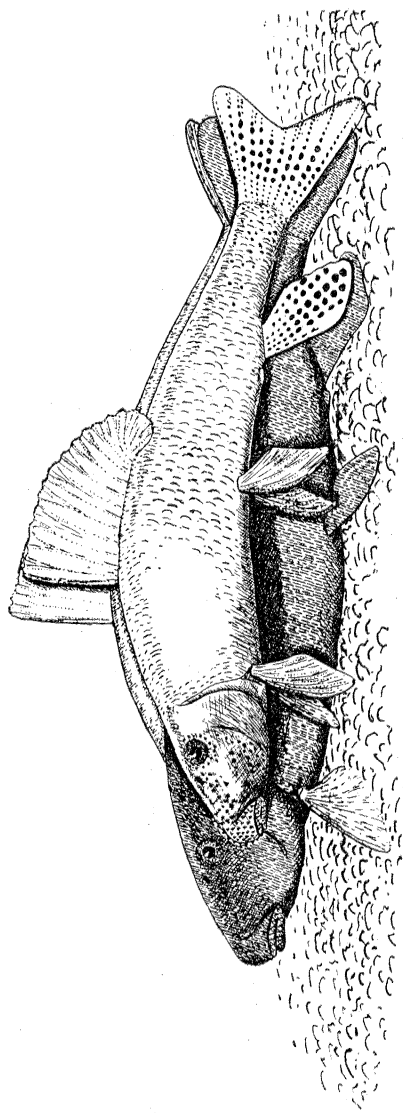


FIG. 5. A female and two males of *Moxostoma auricolum* pairing. The male on the female's left shows the large pearl organs on the caudal and anal, on the sides of the tail and on the head. The smaller pearl organs on the scales of the sides of the male are not represented. The males are not yet in their final position, in which the paired fins are spread, and the pectoral thrust under the female's body. Compare Fig. 6.

than two hundred in a well-developed specimen. On the sides of the anal and caudal fins and on the tail for a little distance in front of the caudal fin are large disc-shaped organs (not pointed). Smaller, pointed organs occur on all the scales of the sides and back, on the dorsal, on the upper surface of the pectoral and on both surfaces of the pelvic. All these organs are effective in proportion to their size. Here again the caudal and anal fins of the male, which exceed those of the female by the largest percentage, bear the largest and most effective pearl organs. It is probable that further data would make possible a more precise statement of the relation between size of pearls and relative size of fins.

This species is one of the few in which pearl organs have been noted in the female. In a single specimen I have found minute organs on the top of the head and on the first few scales of the back behind the head. They were especially numerous about the upper end of the opercular opening. They were too small to be effective and care was needed to see them at all.

3. *Coloration*.—At 2:30 P.M. on May 17, 1904, I found ten to twelve red-horse lying quiet in shallow water near the bank of Mill Creek, near Ann Arbor. The water was smooth and I was able to come within ten feet of them and watch them with field glasses from an elevated position. The fish were from twelve to fourteen inches long from tip of snout to tip of tail.

The red-horse, seen at other seasons, whether in its native waters or in aquaria, has the sides and back in both sexes uniformly olivaceous, but somewhat darker above. The belly is smoky white. The sides show tinges of salmon in front of the dorsals and the lower fins have some orange near the base.

The red-horse before me were of such exceptional coloration that they were at first not recognized. Pectorals, ventrals and anals were bright salmon. Along the sides and running forward above the eye was a white stripe similar to that of the white sucker. It was more prominent in the darker colored individuals but in none of them was a red stripe visible beneath it as in the white sucker. In a few individuals infrequent, elongated white spots were seen above the lateral stripe and running lengthwise of the back. With field glasses pearl organs were visible on

anals and caudal. With good lighting these could be seen with the naked eye at a distance of ten or twelve feet. Subsequent observation showed that all these fish were males.

4. *Breeding Activities*.—The fish were quiet most of the time, but now and then one dropped downstream a few feet and then slowly returned to his original position. Two of them were seen to pick stones from the bottom as though feeding. After an hour and a half a female joined the group of males. She was longer and relatively thicker bodied than the males, not spotted with white on the back and without visible pearl organs. She was at once approached by five males, two of which took position one on either side of her while the other three crowded down from above. One of the upper males was seen to vibrate his tail for a moment but no actual spawning took place at the time. The fish remained grouped for but an instant and then separated. The female went upstream a little way and then dropped back among the males. The group reformed, but immediately broke up again. In these aborted attempts at spawning it was noted that after a single male had placed himself by the side of a female a second male, upon approaching on the same side, turned at once to the unencumbered side. He behaved as though he discriminated between the sexes of the two fish, but by what means this was accomplished I could not tell.

The female again went upstream but this time to a greater distance and followed by two males only. When she had come to rest on the bottom one of the males approached and placed himself by her side. After half a second the other male took his place on her opposite side and spawning occurred very much as in the white sucker (Figs. 5, 6). The backs of the two males were strongly arched so that their dorsal fins were carried well above that of the female and fully spread. Their caudal and anal fins were close pressed against those of the female and against each other as in the white sucker. Their snouts were turned inward and pressed close against the sides of the head of the female below her eyes (Figs. 5, 6).

While the males were in this position with backs bowed and heads straining inward and upward the female was held firmly by the functional pearl organs of their snouts, caudals, anals

and tail. The spawning vibrations lasted two or three seconds. The fish then separated and the female went up stream. Repeatedly after this she dropped down among the males, but when approached by them moved away and did not again spawn. The spawning was not accompanied by any change in color (red stripe) such as was noted in the white sucker.

Except in the attitude of the pairing males the breeding be-

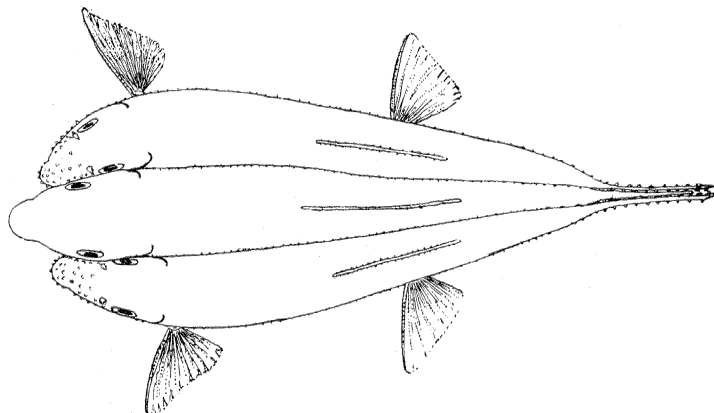


FIG. 6. Dorsal view of a female of *Moxostoma aureolum* pairing with two males. Effective pearl organs are shown. Compare Fig. 5.

havior of the red-horse does not differ essentially from that of the white sucker. The eggs are presumably buried in the bottom as in the white sucker. Those of a single female are scattered in small lots over a considerable bottom area. Those fertilized by a single male are also widely scattered.

C. The Hogsucker (*Catostomus nigricans* Le Sueur).

1. *General Activities*.—*Catostomus* (**Hypentelium**) *nigricans* is known locally in Michigan as the black sucker or pugamoo. Over a wider territory it is known as hogsucker, hogmolly or stoneroller. When not breeding it may often be seen feeding on the rapids of our brooks, creeks and smaller rivers. In feeding, the fish puts its snout under a stone and roots it up or thrusts it sidewise. It then sucks up the slime between the stones and with it obtains immature insects which form its chief diet (Forbes and Richardson, 1908). I have once seen the fish when thus engaged each

accompanied by ten or twelve small shiners (*Notropis*) and by an occasional *Campostoma*. These formed a little school at his sides and below him, and seemed to be waiting for fragments from his feeding.

2. *Sexual Differences*.—In color the sexes appear to be alike at all times. The back and sides are olivaceous, darker above, with dark irregular cross blotches. The belly is satiny white; the lower fins are dull red. Thus the colors of the fish blend with those of the stony bottom on which it is commonly seen. I have determined the following percentage differences in fin lengths (percentage $D = (M - F) : F$) for males and females of the same size based on a single female and the average of two males: caudal — 4.5, anal 17.4, dorsal — 0.2, pelvic 4.2, pectoral — 2.5. These differences are probably within the limits of individual variation except in the case of the anal. The anal of the male thus shows the greatest excess in length over the corresponding fin of the female. The upper and lower caudal lobes are of about equal length in both males and females.

This is one of the few species in which pearl organs are developed in both sexes. In the male (Fig. 7, lower male) they occur on both surfaces of all the fins, on the upper surface of the head, on the opercle and on every scale of the body and tail except those of the ventral surface. The largest organs are those on the anal fin, on the ventral half of the caudal and on the sides of the tail, especially near the caudal fin. Those of the anal reach a diameter of 0.8 mm. and a length of 0.28 mm. in a fish 12 cm. in length, while on the caudal of the same specimen the organs are about 0.5 mm. wide, high and sharp pointed. On the remainder of the fish the organs are small, 0.08 mm. to 0.25 mm. in diameter. All these organs make the surface rough to the touch and are effective in proportion to their size. It is again noteworthy that in the male the anal bears the largest pearls for it is of all the fins the one that shows the greatest percentage of excess length over that of the female. In the female the organs are smaller than those of the male but have a similar distribution. They are absent from the dorsal fin and sides of the body and from the ventral surfaces of pectoral and pelvic. On the anal they are nearly as large as in the male, while on the

caudal they are somewhat smaller, still smaller on the sides of the tail. Those on the anal are distinctly perceptible to touch, those on the caudal and sides of the tail are barely perceptible while the rest are quite imperceptible. Probably only those on the anal are in any degree effective and they are not sharp. It is evident that neither the coloration, the length of the fins, nor the pearl organs afford means of discriminating the sexes in the field. For this purpose one is compelled to rely on the difference in average size and in behavior.

3. *Breeding Activities*.—I have several times seen a single large hogsucker moving upstream in rapids and accompanied or followed by three or four smaller. In one case the large fish was some twelve inches long and the four following her half as long. Occasionally she stopped and one of the smaller fish placed himself by her side. But nothing further occurred and the fish presently moved on.

My only opportunity to observe the actual spawning of this species was on May 4, 1904, in Mill Creek, near Ann Arbor, at the point at which the spawning of the red-horse had been already seen. I was watching the rapids about 4:30 P.M. when a large hogsucker came upstream followed at a short distance by half a dozen others of two thirds her length. Size and behavior indicated the larger fish in this and other cases to be a female. Presently she stopped and remained quiet on the bottom while the males pressed against her three on either side, so close as to hide every part of her except the head and tip of the caudal fin (Fig. 7). The seven fish remained together for several seconds and during this time the female several times made rapidly repeated movements of protrusion and retraction of the mouth. She was not seen to make any other movement nor was any seen in the males. After remaining thus grouped for a fraction of a minute the fish moved on, the female leading. Two somewhat larger males now approached and when the female again stopped these added themselves to the other six, so that the eight of them formed a complete mantle over her back and sides from which only her head and caudal projected. Again the female was seen several times to make rapidly repeated movements of the mouth. The fish then passed out of sight on their way upstream, the female still leading.

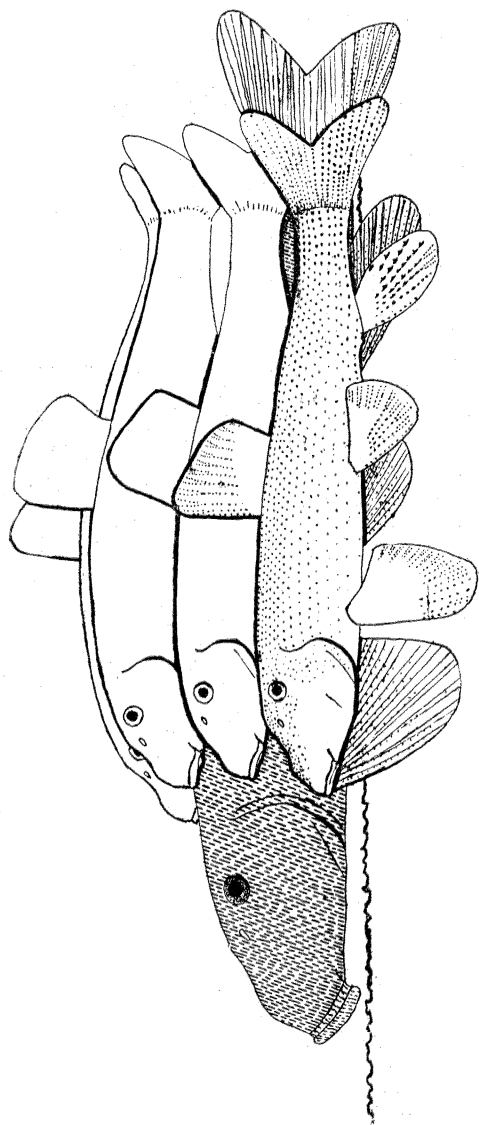


FIG. 7. Lateral view of a female of *Calostomus nigricans* "pairing" with six males, four of which show in the figure. The spots on the lower male and on the fins of the female represent pearl organs. The irregular horizontal line is the bottom.

Although the absence of the vibratory movements characteristic of spawning suggests that the fish whose behavior is described did not actually spawn, the attitudes can be no other than those of spawning fish. These attitudes can be the more readily maintained owing to the general distribution of pearl organs over the surfaces of both sexes. Not only is the occurrence of these organs on the female exceptional, but their distribution in the male is unusual in that they are found on the lower surfaces of the pectoral fins. Males which are above the female presumably have the lower surfaces of the pectorals in contact with her back and sides while those at the sides of the female have the upper surfaces of their pectorals in contact with her belly.

Assuming that the spawning behavior was observed it differs from that of the white sucker in the following particulars. (1) The act is not preceded by change of color; the fish show the same color characters as at other seasons. (2) The act was participated in by more than two males. If it be objected that all but two of the males present were supernumerary, and that the spawning was aborted by their presence as in the case of the white sucker, it may be replied that the fish remained in position long enough to spawn and that those above maintained their positions quietly and did not attempt to displace those below. The whole appearance was that of spawning except for the single feature of lack of vibration.

SUMMARY OF OBSERVATIONS.

A. The White Sucker (Catostomus commersonii).

1. The white sucker breeds in southern Michigan in April and early May.
2. The fish then congregate in the shallow swift water of small streams where the bottom is gravel and sand.
3. At this time both males and females have a yellow-white occipito-lateral stripe not known to occur at other seasons.
4. This stripe is whiter in males than in females and below it on the sides males have a dark lateral stripe often of rosy tinge. The backs of males are often flecked with white not observed in females.
5. The fins of the males exceed those of females of equal

length by the following average percentages; anal and lower lobe of caudal 31 per cent., pectoral 18 per cent., pelvic 11 per cent., dorsal 5 per cent.

6. Effective pearl organs occur in the male on the anal and lower lobe of the caudal on the upper surface of pectorals, on both surfaces of pelvics and dorsals and on the scales of the sides behind the dorsal (Figs. 1, 2, 3).

7. The size of the pearl organs on the fins of the males is roughly proportional to the percentage by which these fins exceed in length the corresponding fins of the female.

8. Females are without pearl organs.

9. In the field males may be distinguished from females by their coloration, by their larger anal fins, by the possession of pearl organs and by behavior.

10. The smallest males and females observed breeding were about six inches long.

11. The males congregate on the rapids and the females remain apart from them in the immediate neighborhood and come to them one or a few at a time.

12. When a female comes to a rapid she is pursued by two or more males.

13. The female intermittently flees from the males but finally stops and permits their approach.

14. The pairing is preceded by a characteristic tremor of the head of the male and preceded or accompanied by a spreading of the fins and a change in the color of the dark lateral stripe from black to a brilliant red.

15. The fins of the males are without conspicuous colors or patterns; yet they are spread by the pairing males just as in certain other species of teleosts in which the spreading displays conspicuous colors or patterns.

16. The female "pairs" with two males at one time (Figs. 2, 3).

17. The two males may be of unequal size and both may be smaller than the female.

18. In the pairing position, one male lies on either side of the female with his pectoral fin spread beneath her and his dorsal elevated. The pearl organs of his sides and of his caudal and anal fins are then in contact with the sides, caudal and anal of the female (Figs. 2, 3).

19. The caudal and anal fins of the two males may project beyond those of the female so that their distal portions are in contact with each other by their roughened surfaces (Figs. 2, 3).

20. The roughened surfaces of the males aid them to hold the female between them.

21. By their contact with each other the roughened surfaces of their caudals and anals may aid the two males to maintain their positions with reference to each other.

22. Spawning is accomplished during a rapid vibration in unison of the bodies of all three fish. This agitates the bottom material and causes its lighter parts to be swept downstream by the current.

23. During spawning milt is seen to spurt from the genital openings of the males and cloud the water.

24. After spawning the fish separate and each may repeat the act many times in various places and in combination with various individuals.

25. Small fish usually gather at once over the area in which the spawning occurred and there crowd together in a small space.

26. These fish root in the bottom with their snouts and appear to be eating eggs that have just been buried.

27. At each pairing act supernumerary males may be present and may attempt to supplant those actually engaged in pairing (Fig. 4).

28. At the close of the breeding season, the pearl organs are shed and both males and females become uniformly olivaceous in color.

29. Outside the breeding season the mature fish are not seen on the rapids in great numbers but in Michigan are abundant in lakes in deeper water.

B. The Red-Horse (Moxostoma aureoleum).

30. Red-horses congregate on the rapids in southern Michigan in May in situations like those occupied by white suckers, but not in streams as small as some of those in which the white suckers breed.

31. In both sexes at this time there is a white lateral stripe,

not observed at other seasons. It extends forward above the eye.

32. The backs of certain males show elongated white flecks running lengthwise, but they do not show the red lateral stripe characteristic of the white sucker at the moment of pairing.

33. The fins of males are longer than those of females of equal length by the following average percentages; lower lobe of caudal 33, anal 14.5, pectoral 16, pelvic 9, dorsal 9.

34. The lower lobe of the caudal of the male is about 14 per cent. longer than the upper lobe.

35. Effective pearl organs occur in the males on all the scales of the back and sides; on both surfaces of caudal, anal, pelvic and dorsal; on the upper surface of the pectoral and on the sides and top of the head to the end of the snout (Fig. 5).

36. Minute non-effective pearl organs occur occasionally in females on the top of the head and on the first few scales of the back behind the head.

37. Of all the fins of the male, the caudal and anal, which exceed the corresponding fins of the female in length by the largest percentage, bear the largest and most effective pearls.

38. The males may be distinguished from the females on the breeding grounds by the pearl organs, by length of anal fin, by behavior and in some cases by differences in coloration (white flecks on the back).

39. The behavior of the fish on the breeding grounds is like that of the white sucker in the particulars stated in paragraphs 11, 12, 13, 14 (except color change), 15, 16, 17, 18, 19, 20, 21, 22, 24, 27, 28.

40. The attitude of the pairing males during spawning differs from that of the white sucker (par. 18) in that the backs are more arched and the snouts with their covering of pearl organs are pressed against the sides of the head of the female (Figs. 4 and 5).

41. In the position indicated in paragraph 40 the female is held not only between the tails, caudals and anals of the two males but between their heads as well.

C. The Hogsucker (Catostomus nigricans).

42. The hogsucker has been seen to breed in early May on the grounds used by the red-horse.

43. No difference in the coloration of the sexes has been noted at any season.

44. The males observed were on the average much smaller than the females.

45. The anal fins of the male are on the average about 17 per cent. longer than these of females of equal length. The remaining fins do not differ greatly from those of the female.

46. Both sexes are provided with pearl organs which are larger and more widely distributed in males than in females.

47. Effective pearl organs occur in the males on both surfaces of all the fins, on the upper surface of the head, on the opercle and on every scale of body and head except those of the ventral surface (Fig. 7, lower male).

48. Pearl organs occur in the female in the same situations as in the male except that they are lacking on the head, sides of body, dorsal fins and lower surfaces of the paired fins. Those of the anal are effective.

49. Of all the fins the anal of the male exceeds that of the female in length by the largest percentage. It also bears the largest and most effective pearls.

50. In the field the sexes may be distinguished by difference in average size and by behavior.

51. The breeding behavior is like that of the white sucker in the particulars enumerated in paragraphs 11, 12, 13, 15, 20, 24.

52. In the hogsucker not less than six nor more than eight males have been seen to "pair" with a single female at one time.

53. In the spawning position one male lies on each side of the female and others place themselves above these and against the sides and back of the female so as to form a mantle about her, from which her head and tip of her caudal may project (Fig. 7).

54. The distribution of pearl organs generally over body and fins in both sexes is such that in the spawning position the surfaces of males in contact with females and with other males as well as certain of the surfaces of females in contact with males are more or less roughened and the fish are thereby the better able to maintain their positions.

CONCLUSIONS.

The breeding behavior of three species of suckers has been studied, the white sucker (*Catostomus commersonii*), the red-horse (*Moxostoma aureoleum*), and the hogsucker (*Catostomus nigricans*). All three make use of similar breeding grounds, the upper parts of rapids, where the water is moderately swift and the bottom gravel and sand. They differ in that some of the streams in which the white sucker breeds are smaller than any frequented by the other two species.

It is possible to discriminate the sexes of all three species on the breeding grounds either by differences in coloration, size of body and fins, pearl organs, behavior, or by some combination of these characters. In all three species the males are seen to congregate on the rapids while the females linger in the neighborhood and enter the rapids at intervals, usually singly, sometimes two or three at once. When a female has come to the rapid she is at once pursued by as many males as happen to be near. She flees, stops, flees as the males again approach, and so continues for some time alternately fleeing and stopping. Sooner or later she comes to rest on the bottom and permits the males to approach. When these have come to her, in the case of the white sucker and the red-horse, two of them pair with her at one time, one on either side. The fins of the males are without conspicuous colors or patterns. Nevertheless during pairing and just before it the males spread their fins after the manner of fish which thereby display conspicuous colors or markings. The display movement occurs, although there is nothing to display. Supernumerary males may approach and by crowding those attempting to pair may interrupt the pairing act. In the hogsucker six or eight males may pair with the female at one time. All appear to take an equal part so that no supernumerary males can be distinguished.

In all three species pearl organs occur on the male and in the hogsucker effective organs occur also on the female. The largest and most effective organs on the fins of the male occur on those fins that exceed the corresponding fins of the female by the greatest percentage of length. In all three species the pairing attitudes are such as to bring into contact with the female those

surfaces of the males roughened by pearl organs. There is at the same time more or less contact with one another of the roughened surfaces of coöperating males and of those of the female of the hogsucker with pairing males. Thus the pearl organs aid the pairing fish to keep their positions with relation to one another in the swift water during the vigorous vibrations which characterize spawning. These vibrations are very pronounced in the white sucker and red-horse but have not been observed in the hogsucker. They continue in the white sucker for about a second and a half and during that time the tails of the fish agitate the bottom and the lighter bottom materials are swept down stream by the current.

When the pairing white suckers have separated, their eggs are left buried in the bottom. This is inferred from the behavior of the numerous minnows which congregate over the spot. The similarity of spawning behavior indicates that the eggs of the other species are buried in similar fashion.

The females of the species studied deposit eggs in various parts of the breeding ground and in doing so each pairs with many males. It results from the breeding activities that the eggs of a single female are widely scattered and are fertilized by many

$$\begin{array}{cccc}
 wAz & yBz & zCw & xDz \\
 wCx & yDx & wAy & xBz \\
 yBx & yAx & zDy & wCy \\
 wDz & wBx & zCy & xAz \\
 xAy & xDw & wBy & yCx \\
 xCz & zBw & xAw & wDy
 \end{array}$$

FIG. 8. Showing the distribution of pairings and their character over the spawning area in the case of suckers in which two males pair with one female. A, B, C, D, females; w, x, y, z, males.

males. It results further that the sperm of a single male fertilizes the wide-scattered eggs of many females. The coöperation of at least two males in pairing with a single female makes it impossible to know the male parentage of a given embryo. This same coöperation makes it impossible that the eggs deposited in any small, continuous bottom area should be fertilized by one male. They are in fact not fertilized by one pair of males. The rela-

tions of the sexes are as indiscriminate as they well can be. We may represent four females of the white sucker or red-horse by the letters *A, B, C, D*, and four males by the small letters *w, x, y, z*. Six pairs may be formed with the four males, *wx, wy, wz, xy, xz, yz*. Assuming that each female spawns once with each pair of males and that her spawnings are distributed at random over the breeding ground we should have some such space-distribution of pairings as shown in Fig. 8. In the hogsucker in which one female pairs with more than two males the relations would be still more complicated.

No male occupies any particular locus of the spawning ground and attempts to defend it against other males. On the contrary each male is free to wander over the whole spawning ground. He may "pair" in any part of it, for he does not enter into combat with other males but coöperates with them. The female does not restrict her activities to any part of the spawning ground. Were she to do so she would be finally beset by so many males that normal pairing might be difficult or impossible. She does not actively reject any of the males, but when beset by so many that spawning is difficult, she seeks a new locus. This she continues to do until normal pairing becomes possible. She may be said to try various situations of the spawning ground until she finds one in which the conditions permit spawning. This relation of the sexes is neither polyandry nor polygamy. It is promiscuity, corresponding to the hypothetical communal marriage of primitive man. It occurs along with lack of combat amongst the breeding fish. Where combat occurs, as in minnows, promiscuity gives place as will be shown in later papers, to a sex relation that approaches polygamy.

LITERATURE CITED.

Boulenger, G. A.

- '04 Teleostei, systematic part, in *The Cambridge Natural History*, Vol. VII., pp. 541-727. London.

Forbes, S. A. and Richardson, E. R.

- '08 *The Fishes of Illinois*, pp. cxxxi-357, text and atlas of 103 maps, with 40 colored plates, 15 black and white plates, and 76 figures in the text. Urbana.

Hankinson, T. L.

- '08 *A Biological Survey of Walnut Lake, Michigan. A Report of the Biological Survey of Michigan*, published by the State Board of Geological Survey as a part of the report for 1907, pp. 157-288, pl. XIII.-LXXV., 6 text figs. Lansing.

Parker, G. H.

- '17 The Reception of Mechanical Stimuli by the Skin, Lateral-line Organs and Ears in Fishes, Especially in *Amiurus*. *Am. Jour. Phys.*, XLV., 463-489. Published also as Contribution from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, no. 298. Cambridge.

Reeves, Cora D.

- '07 The Breeding Habits of the Rainbow Darter (*Eltheostoma caeruleum* Storer), a Study in Sexual Selection. *BIOL. BULL.*, XIV., 35-57. 3 text figures Lancaster.

Reighard, Jacob.

- '04 Further Observations on the Breeding Habits and on the Function of the Pearl Organs in Several Species of *Eventognathi*. *Science*, Vol. XIX., p. 212.
- '15 An Ecological Reconnoissance of the Fishes of Douglas Lake, Michigan, in Midsummer. *Bulletin of the U. S. Bureau of Fisheries*, Vol. XXXIII. (for 1913), pp. 219-249, map and ten tables. Document no. 814, U. S. Bureau of Fisheries. Washington.